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AUTHOR Lombard, Anne S.
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ABSTRACT

A study investigated whether teachers who participated in "Science Teaching and The Development of Reasoning" workshops felt they utilized the ideas of the workshop in changing their learning style and methods. It determined the nature and extent of changes made which were consistent with the intent and philosophy of the workshop and identified those factors teachers perceived as either facilitating or hindering their ability to make changes. Of the 1000 teachers who participated in the workshop, 110 teachers answered a 29 item questionnaire which included items on demographic data, application of workshop ideas, and a five-point Likert scale concerning the philosophy of the workshop. Individual interviews (N=20), telephone interviews (N=20), and the Stages of Concern Questionnaires (N=21) were also used to assess participants' attitudes and use of workshop ideas. Findings indicate positive responses in attitudes, teaching styles, and methods as a result of the workshop. (DS)

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THE EFFECTS OF REASONING WORKSHOPS ON THE TEACHING STRATEGIES OF SECONDARY SCIENCE TEACHERS

Anne S. Lombard

Center for Research in
Applied Developmental Theory
School of Education
University of Massachusetts
Amherst, Ma.

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Introduction

Every science teacher has experienced students who seem unable to grasp abstract concepts, as well as other students who understand these same concepts readily. The interest of science educators is now becoming focused on the student who is unable to understand and retain certain concepts, who uses inappropriate reasoning strategies, and who is unable to transfer methods of solving problems to new situations.

In the past decade, much research has been done applying the theories of Jean Piaget to the developmental thinking processes of students in the United States. John Renner, Anton Lawson, Robert Karplus, and others have been involved in research attempting to determine, in light of Piaget's theories, how secondary students learn science concepts (Lawson, Karplus & Adi, 1978). Evidence suggests that the level of thought of children of all ages is changed when they are exposed to inquiry-centered experiences in science (Lawson and Wollman, 1975; McKinnon and Renner, 1970). New programs have been funded and developed, but increase in content of each course rather than change in teaching strategies has been the primary result. Teachers tend to use new materials in traditional ways.

In work done by Robert Karplus and Associates, an instructional program for secondary science teachers has been developed incorporating Piagetian theory. These workshops attempt to give teachers the skills to assess their students' reasoning levels, to become aware of the types of reasoning used in science texts, to become familiar with Piaget's theories of developmental

reasoning, and to apply Piaget's ideas to instructional methods (Karplus, 1977; Karplus, et al., 1977).

These Science Teaching and Development of Reasoning workshops model a three-phased learning cycle which includes exploration, concept introduction, and concept application. This learning cycle, originally used in the elementary school science program, developed by the Science Curriculum Improvement Study (SCIS) at the University of California at Berkeley, has been found to be an effective teaching approach for adults as well as for children of all ages (Karplus, 1979).

During the first or Exploration phase, students are encouraged to explore new ideas and materials. Because the learning is done through their own actions and reactions in a new situation, guidance and expectations are limited. New experiences with concrete materials raise questions not answerable by former patterns of reasoning.

The second phase, Concept Introduction, includes the presentation of a new concept or principle which guides the students in applying new patterns of reasoning to their experiences. This relates directly to the exploration activities and leads towards self-regulation.

In Piagetian terms, when a learner is exposed to new information for which s/he does not have the available mental structures to allow its assimilation, s/he is in disequilibrium. The role of the teacher at this point can be to suggest ways of ordering the experience by introducing a new concept.

During the workshop, teachers model the "learning cycle" approach by doing several problems involving proportion and control of variables followed by an examination of student responses to these problems. Only following this "exploration" are they introduced to the concept of "reasoning patterns" by

learning to identify and distinguish those used most frequently by secondary science students.

In the last phase, Concept Application, further activities are presented which involve the same conceptualization. As an example, the workshop participants apply the concept of "reasoning patterns" by dividing student responses into categories and examining texts and other curricular materials in terms of cognitive requirements. Thus, the application phase reinforces the new concept.

Background and Purpose of the Study

During the Fall of 1978, leaders in science education at twelve universities, colleges, and secondary schools throughout New England were trained to give Science Teaching and Development of Reasoning workshops. During the following year, workshops were presented by these trained leaders to teachers throughout New England, both at conferences and at individual schools.

The purpose of the study described in this paper was to determine whether teachers who participated in Science Teaching and Development of Reasoning workshops during 1978 through 1979 felt that they had utilized the ideas of the workshop in changing their teaching style and methods, to determine the nature and extent of changes made which were consistent with the intent and philosophy of the workshop, and to identify what factors the teachers perceived either facilitated or hindered their ability to make changes.

Procedure

From over one thousand teachers who attended Science Teaching and Development of Reasoning workshops in New England, 210 were selected for participation in

this study. Those selected included all secondary science teachers who attended workshops which exceeded three hours in length, and whose addresses had been recorded.

A twenty-nine item questionnaire was developed and submitted for validity to three authors and consultants involved in the developing of the workshop, the 12 subcenter directors, four inservice specialists, and three educational research specialists. The questionnaire consisted of three parts:

1. Demographic data about the respondents (See Table 1).
2. Questions employing a five-point Likert scale which identified the characteristics and philosophy of the workshop itself, applications of the ideas presented in the workshop, and factors in the school environment relevant to effective science inservice programs.
3. An open-ended question asking for specific examples of application of ideas from the workshop.

The questionnaire was tested for reliability by using a test-retest procedure. A group of twenty, who responded initially to the questionnaire were retested one month following their original filling out of the questionnaire, to assess the stability of the instrument over a short period of time. A Pearson correlation coefficient of 0.8 was found.

Insert Table 1 About Here

Teachers responding to the workshop evaluation questionnaire, who were willing to be interviewed regarding their use of workshop materials and ideas, were requested to submit their name, address, and telephone number separately from the questionnaire. Of the one hundred and ten returned questionnaires, thirty-one individuals indicated a willingness to be

interviewed. Twenty of the thirty-one were selected at random to be interviewed.

A list of factors affecting use of the workshop was used as a guideline in designing the interview questions. The interview guide consisted of questions which focused the direction of the interview, but also allowed latitude for the interviewer.

Teacher-prepared materials, such as tests, laboratory outlines, supplementary explanations, or review questions that illustrated the effects of the workshop on teaching were also requested. These provided data to determine the nature and extent of changes made.

Twenty randomly sampled non-respondents to the questionnaire were interviewed by telephone to determine their attitude towards the workshop. This was done to provide a basis of comparison with the teachers who responded to the questionnaire. The same interview guide as in the previously described interviews was used.

Results

Attitudinal Change

The frequency distributions of the responses to items on the Workshop Evaluation Questionnaire which report changed attitudes, teaching style, and methods are shown in Table 2. Of the one hundred and ten science teachers who responded to the questionnaire, eighty-nine percent indicated that they had become more aware of the reasoning processes of their students, and seventy-nine percent felt that they should plan or teach some of their classes differently as a result of the workshop. Seventy-five percent felt that they could incorporate the ideas of the workshop into their teaching, whereas seventy-

three percent indicated that some change in their teaching had occurred as a result of participating in the workshop. Table 3 indicates the extent to which the responding teachers felt they had applied the ideas of the workshop in the areas of laboratory design, textbook use, introduction of new topics, presentation of concepts, and testing. The greatest amount of change was reported in the introduction of new topics and the presentation of concepts and the least in the use of the textbook.

Insert Tables 2 & 3 About Here

Of the twenty teachers who were interviewed, all were positive about the workshop, but they divided into three groups with regard to their level of use of the workshop ideas. Four were already familiar with the information and orientation from reading or from previous workshops and reported using the ideas in their classes. They attended the workshop to gain further information and ideas for application.

Half of the interviewees reported having made distinct changes since attending the workshop. The third group of six felt that their awareness of the reasoning processes of students had been raised, but that they had not made specific changes.

Curriculum Changes

The extent of curriculum change reported by the teachers varied widely. At one end of the spectrum were teachers who were experimenting with new ways of presenting topics in the classroom and who had revised one or two laboratories to make them more open-ended. Of the teachers who had done more extensive development and revision of the curriculum, one developed

a whole unit, another a series of laboratories following the models experienced in the workshop. Tables 4 and 5 show the types of curriculum changes that have been made and the number of instances of reported change.

Insert Tables 4 & 5 About Here

The greatest number of changes were reported in methods of presenting topics and introducing concepts, with the least number of changes in use of textbooks. These results were similar to those from the Workshop Evaluation Questionnaire with regard to relative frequency of changes in the different aspects of science teaching.

Analysis of interview transcripts and curriculum materials provided by teachers reveals varying interpretations on the part of the teachers with regard to the meaning of the terms "concrete", "formal", and "exploration", three important concepts upon which the workshop is based.

A common misconception was that using "concrete" methods of presentation, such as diagrams, demonstrations, models, historical and everyday examples, and discovery type experiments make a concept which requires formal operational thought to understand, more concrete. A confusion existed between effective teaching methods and those which promote cognitive development. Concrete models and analogies may be effective ways to illustrate formal concepts, but there is no evidence to indicate that concrete operational thinkers will move to formal operational thought with respect to a certain concept as a result of exposure to these models.

Only four of the twenty teachers interviewed mentioned eliminating the teaching of concepts which require formal operational thinking in their

classes. This suggests that many continue to teach formal concepts to students who are not developmentally prepared to understand them.

The concept of "the learning cycle", the idea of placing a laboratory activity or "exploratory" activity before presentation of the main concepts of the unit, had reportedly been used by seven of the twenty teachers interviewed. No agreement existed, however, on what the term "exploration" meant. Examples described and/or sent by workshop participants showed a range from relatively structured laboratory exercises and demonstrations to a totally unstructured experimentation with materials.

All of the teachers interviewed expressed reservations about the concept of a completely open exploration, the "here are the materials; see what you can discover" approach. One problem was the amount of time necessary to implement such an approach. Another was classroom management, control, and safety. In spite of a variety of interpretations of the meaning of "exploration", more than twenty specific examples of laboratories and field experiences were described as "exploratory" by the questioned and interviewed teachers, all of which showed a tendency to move away from teacher direction towards increased activity and initiative on the part of the student.

Telephone Interviews With Non-Responders

Telephone interviews were conducted with a random sample of twenty of the ninety teachers who had not returned the questionnaire. The intent of these interviews was to determine:

-- Attitudes towards the workshop;

-- Understanding and recall of ideas of the workshop;

-- Use of ideas from the workshop.

Four of the twenty interviewed stated that they had retained good comprehension of the workshop content and purpose and that they were using the resulting ideas. Nine additional teachers from this interviewed group were positive about the workshops but stated that they needed either more time or follow-up workshops to assist in assimilation of the material. They stated that their awareness had increased regarding the importance of reasoning in the classroom, but they had done little to change their curriculum. Recall of workshop ideas among this group was considerably less than among the previous four. Five from this group mentioned that they did not return the questionnaire because they could not remember the workshop well enough. Two indicated that they were planning to take follow-up courses the following semester.

The final group of seven, including two who did not return for the second part of the workshop, stated that they had not found the workshop useful.

Factors Affecting Teacher Change

In response to questions posed during the interviews, numerous factors were mentioned by the teachers which they felt limited their ability to apply the ideas of the workshop in their classrooms. These are listed in Table 6.

Insert Table 6 About Here

The primary factors were:

-- Insufficient time during and following the workshop to understand and assimilate the ideas.

-- Insufficient knowledge about the reasoning requirements of curriculum they are teaching, including application in specific subject areas.

-- Insufficient time in schools for preparation and revision of curriculum.

-- Isolation from professional colleagues who have similar interests.

Changes in the classroom occur to the extent that administrative support is translated into time, both in class preparation, in scheduling, and in curriculum demands. Administrative and peer support result in improved morale which provides the atmosphere for innovation. Teachers described the support problems involved in changing their teaching style and course material in the direction of increased emphasis on reasoning.

Discussion and Implications

Change is more likely to occur when teachers choose to be involved in the initiation and development of their own inservice programs. Ideally, Science Teaching and Development of Reasoning workshops should be teacher initiated and attendance should be voluntary. More teacher input into the format and ideas of the workshop enhances its effectiveness. Requesting teachers to bring in the texts they are using, laboratory directions and tests they have given, and using these as the basis of analysis in addition to or instead of those provided by the workshop has been successful in increasing relevancy and teacher involvement.

The lack of time during most workshops to assimilate the complex ideas of the workshop needs to be addressed.

Analysis of the interviews and curriculum materials already developed revealed a considerable variation in interpretation of concrete and formal

operational reasoning, as well as the concept of exploration. This lack of clarity is partly due to the fact that one or several workshops do not provide enough time and experience for understanding these concepts, as well as the complexity of the concepts themselves. It must be made clear to administrators and teachers who request workshops, that a few hours provide only an introduction and superficial familiarity with potential applications of Piagetian theory. Opportunity for follow-up sessions needs to be made available to interested teachers. This is happening in the New England area with the development of a project enabling forty secondary science teachers to continue to meet periodically to share and evaluate curriculum they have developed based on this model. This will also supply the colleague support considered necessary by all the teachers who were interviewed.

The implications from this study are both theoretical and practical. Research is needed to clarify the characteristics of formal operational thought with respect to the different subject matter areas of science. In the Science Teaching and Development of Reasoning workshops, both the educational objectives, i.e., to achieve or move in the direction of formal operational thought, and the educational methods (physical experience, social interactions, and equilibration) are derived from the theories of Jean Piaget (Piaget, 1964, 1972). Some of the difficulties in applying this theory to education arise from the lack of specificity of the theory as well as the fact that it has been applied to education by those other than Piaget, by individuals who have interpreted it in a variety of ways.

Curriculum cannot be based on developmental stages until the competencies of these stages are more fully defined in all contexts. "Ecosystem" or

"evolution" may be formal operational concepts. But what indicates the use of formal operational reasoning in relation to these concepts, and in what context would it be used? What is needed are examples of concrete and formal reasoning strategies as they are observed during the students' activities. Deanna Kuhn (1979) states that unless we have descriptions of how students reason, we will not understand the competencies which should be produced, their nature or their significance. How will we know when we observe particular thought processes of the students in activities we design? The key is to observe students carefully when they are working on a problem. It will be a challenging task to figure out how formal operational reasoning shows up in each conceptual domain of the curriculum. According to Kuhn, this is a task which the developmental researchers and educators must accomplish together.

Once the above clarification has been achieved, then inservice programs that have impact on the teachers and students involved need to be developed.

This study has shown that a single workshop on the development of reasoning can result in at least half of the participating teachers realizing the importance of reasoning development and beginning to focus on it. Some knowledge of the concepts was also achieved. But few developed the skills to transfer the concepts and suggested approaches to the classroom. Joyce and Showers (1980) describe five components which contribute to the impact of an inservice training program:

a. Presentation of theory or description of a skill or strategy;

b. Modeling or demonstration of skills;

c. Practice in simulated and classroom settings;

d. Structured and open-ended feedback;

e. Coaching for application (hands-on, in-classroom assistance with the transfer of skills and strategies to the classroom) (p. 380).

Programs need to be developed which incorporate various combinations of these elements. They can then be evaluated to determine which combination of training elements has the most impact.

As more teachers become familiar with developmental theory and begin to apply it, the question arises as to how much this theory should be involved in making decisions about educational policy and practice. This is a crucial question because of the current tension between developmentally based and traditional or back-to-basics curricula.

Therefore, inquiry-oriented, laboratory-centered courses using the learning cycle model, which have the goal of increasing students' understanding of concepts by making instruction appropriate to their developmental level as well as promoting formal operational thought relevant to the domain of the course (Feldman, 1980) need to be compared with traditionally taught high school science courses. These courses should be compared with respect to:

a. Increased ability of students to use formal thought;

b. Subject matter content learned;

c. Attitudes of students towards the course.

A final consideration relates to observations that teachers and learners all have different belief systems, personalities, teaching and learning styles. No single approach is optimal for all. The ideas from the workshop have generated many adaptations influenced by the classroom style of teachers and the needs and interests of students.

Harvey (1970) found that both teachers and students can be grouped in

terms of their need for structure, attitude towards transition, authority, open-mindedness, problem-solving orientation, and ability to behave creatively. The majority, according to Harvey's research, enjoy traditional roles, authoritarian approaches, and resist innovation. Students with a high need for structure and guidance reacted negatively towards teachers strong in the qualitites of abstract thinking, open-mindedness, with a strong problem-solving orientation. The converse was true for children low in need of structure and high in independence.

Freedom then, subjectively is providing an environment which meets each individual's need at a particular time. For some, this means providing external structure; for others, allowing individual decision-making.

To take this line of argument a step further, ways need to be found for secondary science teachers who are interested in following more exploratory, non-structured methods in their classrooms to be provided with students who will most benefit from this approach.

Because of these different attitudes and personality styles, there is no way to package innovation successfully. It is a process of mutual adaptation through which each user progresses according to ability and inclination. Likewise, "learning cycles" and other approaches may have to be reinvented by each teacher attempting to promote reasoning in the classroom. Then, with the right combination of teacher and student, will the exciting dynamic of change and growth be possible.

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TABLE 1

DATA REGARDING THE TEACHERS WHO RESPONDED TO THE QUESTIONNAIRE

1.	Present Grade or Teaching Level	Below 7 6.4%	7th-9th 34.5%	10th-12th 56.4%	
2.	Total Number of Years Teaching	1-4 Years 13.6%	5-10 Years 27.3%	Over 10 Years 58.2%	
3.	Total Number of Workshop Hours Attended	3-4 Hours 10.9%	5-6 Hours 48.2%	More Than 6 40.9%	
4.	Number of Months Passed Since Attending Workshop as of April 1, 1980	0-3 Months 7.3%	4-6 Months 51.8%	More Than 6 40.0%	
5.	Sex of Participants	Female 34.5%	Male 64.5%		
6.	Subject Area of Major Teaching Responsibility	Physics: Biology: Chemistry: General Science: Earth Science: Other:	11.8% 26.4% 17.3% 30.0% 3.6% 9.1%		
7.	Highest Degree Earned	B.A.: 27.3% M.A.: 67.3%	Doctorate: 4.5% Other: .9%		
8.	Average Class Size	15 25.5%	20 39.1%	25 28.2%	30 And Up 5.5%
9.	Participation in the Workshop	Voluntary: Mandatory:	86.4% 13.6%		
10.	Release Time to Attend the Workshop	Yes 62.7%	No 22.7%	Irrelevant 14.5%	

NOTE: Percentages are based on 110 responses to the Workshop Evaluation Questionnaire. Missing values from respondents who did not answer certain questions account for totals not being 100%.

TABLE 2

EFFECTS OF SCIENCE TEACHING AND THE DEVELOPMENT OF REASONING WORKSHOPS

	Yes	No	Undecided
As a result of the workshop teachers became more aware of the reasoning processes of their students.	89.1%	6.4%	4.5%
Teachers felt they could incorporate the ideas of the workshop into their teaching.	75.5%	18.2%	6.3%
The teachers felt they should plan or teach some of their classes differently as a result of the workshop.	79.1%	12.7%	8.2%
The teachers felt that some change in their teaching had occurred as a result of participating in the workshop.	73.6%	14.5%	11.9%

NOTE: Percentages are based on 110 responses to the Workshop Evaluation Questionnaire. A grouping of data was made for clarification.

TABLE 3

APPLICATION OF THE IDEAS OF SCIENCE TEACHING AND DEVELOPMENT OF REASONING WORKSHOPS IN LABORATORY DESIGN, USE OF TEXTBOOKS, INTRODUCING NEW TOPICS, PRESENTING CONCEPTS, AND TESTING

	Not At All to Very Little	Moderately to Considerably	Undecided or Not Applicable*
Laboratory Design	37.2%	49.1%	13.7%
Use of Textbook	42.8%	44.5%	12.7%
Tests	30.0%	60.9%	9.1%
Introducing New Topics	20.0%	72.6%	7.4%
Presentation of Concepts	13.7%	80.0%	6.3%

NOTE: Percentages are based on 110 responses to the Workshop Evaluation Questionnaire. A grouping of data was made for clarification.

*Some teachers do not include laboratories in their courses; others do not use a text.

TABLE 4

CHANGES IN TOPIC PRESENTATION/CONCEPT INTRODUCTION AND LABORATORY DESIGN AND PROCEDURE IN THE SECONDARY SCIENCE CLASSROOM AS A RESULT OF ATTENDING SCIENCE TEACHING AND THE DEVELOPMENT OF REASONING WORKSHOPS

	Number of Instances of Reported Change*
Topic Presentation and Concept Introduction	
New concepts introduced at a concrete operational level before progression to a formal operational level	11
Increased emphasis on problem-solving; moving from a lecture format to increased use of questions	8
Concepts, text sections, and laboratories which require formal operational thinking eliminated from certain courses	4
Answers to problems given with credit provided for reasons	3
A whole unit written with a problem-solving approach	1
Laboratory Design and Procedure	
Laboratory or exploratory activity placed at the beginning of the unit before presentation of main concepts of the unit in class or text (i.e., learning cycle)	7
Increased number of laboratories in which students develop their own procedure	6
Laboratories simplified to emphasize concrete reasoning and to emphasize more student input	3
Materials (i.e., bulbs and batteries) handed out without telling students objectives or suggested procedure	2

*Reports from twenty interviewed teachers

TABLE 5

CHANGES IN TEXTBOOK USAGE AND EVALUATION PROCEDURES IN THE SECONDARY SCIENCE CLASSROOM AS A RESULT OF ATTENDING SCIENCE TEACHING AND THE DEVELOPMENT OF REASONING WORKSHOPS

	Number of Instances of Reported Change*
Textbook Usage	
Parts of science texts rewritten with the goal of making them more concrete	5
Use of a science text discontinued in favor of a new text more appropriate for the reasoning skills of students	2
Text discussing a subject assigned after the laboratory experience on the same subject	1
Evaluation	
Piagetian-type problems used for diagnostic and placement purposes	7
Tests altered to include questions which involve concrete operational reasoning as well as questions which involve formal reasoning	3
Questions requiring formal operational reasoning added at the conclusion of the test to stimulate those in transitional stages	2
A reason for each answer required when objective tests are used	2
Tests designed to provide a sequence from concrete to formal	1

*Reports from twenty interviewed teachers

TABLE 6

FACTORS MENTIONED BY TEACHERS DURING THE TWENTY USER INTERVIEWS WHICH LIMITED THEIR ABILITY TO APPLY THE IDEAS OF THE WORKSHOP IN THEIR CLASSROOMS

Factors	Number of Teachers Who Mentioned It
Lack of knowledge, including application in specific subject areas	15
Isolation from other interested teachers	14
Lack of preparation time	12
Necessity of covering content	5
Administrative lack of support	2
Parent expectations	2
Text used is differently oriented	2
Refusal to sacrifice content for reasoning emphasis	2
No way to test the learning that has taken place	1
Heterogenous groups in classes	1
Physical facilities	1
Class size	1
Lack of supervision	1
Inertia	1

*These factors were mentioned by teachers spontaneously during the interview. They were not articulated specifically by the interviewer.